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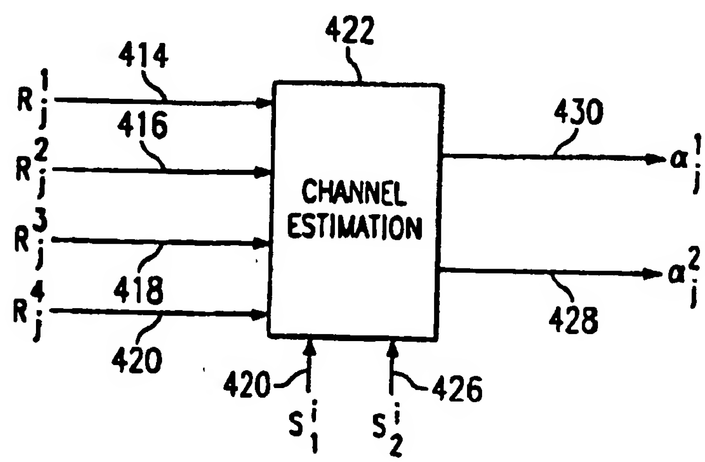
(54) Channel estimation in space time block coded transmit antenna diversity for WCDMA

(57) A circuit is designed with an estimate circuit (422) coupled to receive a plurality of input signals (R_j^1, R_j^2) from an external source along a plurality of paths (j) and at least one known signal (S_1). The at least one known signal has a predetermined value. The estimate circuit produces a plurality of estimate signals (α_j^1, α_j^2) corresponding to each respective signal path in response to the plurality of input signals and the at least one known signal. A correction circuit (350) is coupled to receive the plurality of estimate signals and the plurality of input signals. The correction circuit produces a first symbol estimate (S_m) in response to the plurality of estimate signals and the plurality of input signals. The correction circuit produces a second symbol estimate (S_n) in response to the plurality of estimate signals and the plurality of input signals.

FIG. 4B



EP 0 993 129 A2

Description

FIELD OF THE INVENTION

[0001] This invention relates to wideband code division multiple access (WCDMA) for a communication system and more particularly to space time block coded transmit antenna diversity for channel estimation of WCDMA signals.

BACKGROUND OF THE INVENTION

[0002] Present code division multiple access (CDMA) systems are characterized by simultaneous transmission of different data signals over a common channel by assigning each signal a unique code. This unique code is matched with a code of a selected receiver to determine the proper recipient of a data signal. These different data signals arrive at the receiver via multiple paths due to ground clutter and unpredictable signal reflection. Additive effects of these multiple data signals at the receiver may result in significant fading or variation in received signal strength. In general, this fading due to multiple data paths may be diminished by spreading the transmitted energy over a wide bandwidth. This wide bandwidth results in greatly reduced fading compared to narrow band transmission modes such as frequency division multiple access (FDMA) or time division multiple access (TDMA).

[0003] New standards are continually emerging for next generation wideband code division multiple access (WCDMA) communication systems as described in Provisional U.S. Patent Application No. 60/082,671, filed April 22, 1998, and incorporated herein by reference. These WCDMA systems are coherent communications systems with pilot symbol assisted channel estimation schemes. These pilot symbols are transmitted as quadrature phase shift keyed (QPSK) known data in predetermined time frames to any receivers within range. The frames may propagate in a discontinuous transmission (DTX) mode. For voice traffic, transmission of user data occurs when the user speaks, but no data symbol transmission occurs when the user is silent. Similarly for packet data, the user data may be transmitted only when packets are ready to be sent. The frames are subdivided into sixteen equal time slots of 0.625 milliseconds each. Each time slot is further subdivided into equal symbol times. At a data rate of 32 KSPS, for example, each time slot includes twenty symbol times. Each frame includes pilot symbols as well as other control symbols such as transmit power control (TPC) symbols and rate information (RI) symbols. These control symbols include multiple bits otherwise known as chips to distinguish them from data bits. The chip transmission time (T_c), therefore, is equal to the symbol time rate (T) divided by the number of chips in the symbol (N).

[0004] Previous studies have shown that multiple transmit antennas may improve reception by increasing transmit diversity for narrow band communication systems. In their paper New Detection Schemes for Transmit Diversity with no Channel Estimation, Tarokh et al. describe such a transmit diversity scheme for a TDMA system. The same concept is described in A Simple Transmitter Diversity Technique for Wireless Communications by Alamouti. Tarokh et al. and Alamouti, however, fail to teach such a transmit diversity scheme for a WCDMA communication system.

[0005] Other studies have investigated open loop transmit diversity schemes such as orthogonal transmit diversity (OTD) and time switched time diversity (TSTD) for WCDMA systems. Both OTD) and TSTD systems have similar performance. Both use multiple transmit antennas to provide some diversity against fading, particularly at low Doppler rates and when there are insufficient paths for the rake receiver. Both OTD and TSTD systems, however, fail to exploit the extra path diversity that is possible for open loop systems. For example, the OTD encoder circuit of FIG. 5 receives symbols S_1 and S_2 on lead 500 and produces output signals on leads 504 and 506 for transmission by first and second antennas, respectively. A despreader input circuit (FIG. 4A) receives these transmitted signals. The despreader circuit sums received chip signals over a respective symbol time to produce first and second output signals R_j^1 and R_j^2 on leads 620 and 622 as in equations [1-2], respectively.

$$R_j^1 = \sum_{i=0}^{N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 + \alpha_j^2 S_2 \qquad [1]$$

$$R_j^2 = \sum_{i=N}^{2N-1} r_j(i+\tau_j) = \alpha_j^1 S_1 - \alpha_j^2 S_2 \qquad [2]$$

[0006] The OTD phase correction circuit of FIG. 6 receives the output signals R_j^1 and R_j^2 corresponding to the j^{th} of L multiple signal paths. The phase correction circuit produces soft outputs or signal estimates $\tilde{S}_1$ and $\tilde{S}_2$ for symbols S_1 and S_2 at leads 616 and 618 as shown in equations [3-4], respectively.

$$\tilde{S}_1 = \sum_{j=1}^{L}(R_j^1 - R_j^2)\alpha_j^{1*} = \sum_{j=1}^{L}2|\alpha_j^1|^2 S_1 \qquad [3]$$

$$\tilde{S}_2 = \sum_{j=1}^{L}(R_j^1 - R_j^2)\alpha_j^{2*} = \sum_{j=1}^{L}2|\alpha_j^2|^2 S_2 \qquad [4]$$

Equations [3-4] show that the OTD method provides a single channel estimate α for each path j. A similar analysis for the TSTD system yields the same result. The OTD and TSTD methods, therefore, are limited to a path diversity of L. This path diversity limitation fails to exploit the extra path diversity that is possible for open loop systems as will be explained in detail.

SUMMARY OF THE INVENTION

[0007] These problems are resolved by a circuit comprising an estimate circuit coupled to receive a plurality of input signals from an external source along a plurality of paths and at least one known signal. The at least one known signal has a predetermined value. The estimate circuit produces a plurality of estimate signals corresponding to each respective signal path in response to the plurality of input signals and the at least one known signal. A correction circuit is coupled to receive the plurality of estimate signals and the plurality of input signals. The correction circuit produces a first symbol estimate in response to the plurality of estimate signals and the plurality of input signals. The correction circuit produces a second symbol estimate in response to the plurality of estimate signals and the plurality of input signals.

[0008] The present invention improves channel estimation by providing at least $2L$ diversity over time and space. No additional transmit power or bandwidth is required. Power is balanced across multiple antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the invention may be gained by reading the subsequent detailed description with reference to the drawings wherein:

FIG. 1 is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention;

FIG. 2 is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1;

FIG. 3 is a schematic diagram of a phase correction circuit of the present invention that may be used with a receiver;

FIG. 4A is a block diagram of a despreader circuit of the prior art that may be used with STTD of the present invention;

FIG. 4B is a block diagram of a channel estimation circuit that may be used with STTD of the present invention;

FIG. 5 is a block diagram showing signal flow in an OTD encoder of the prior art; and

FIG. 6 is a schematic diagram of a phase correction circuit of the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Referring to FIG. 1, there is a simplified block diagram of a typical transmitter using Space Time Transit Diversity (STTD) of the present invention. The transmitter circuit receives pilot symbols, TPC symbols, RI symbols and data symbols on leads 100, 102, 104 and 106, respectively. Each of the symbols is encoded by a respective STTD encoder as will be explained in detail. Each STTD encoder produces two output signals that are applied to multiplex circuit 120. The multiplex circuit 120 produces each encoded symbol in a respective symbol time of a frame. Thus, a serial sequence of symbols in each frame is simultaneously applied to each respective multiplier circuit 124 and 126. A channel orthogonal code C_m is multiplied by each symbol to provide a unique signal for a designated receiver. The STTD encoded frames are then applied to antennas 128 and 130 for transmission.

[0011] Turning now to FIG. 2, there is a block diagram showing signal flow in an STTD encoder of the present invention that may be used with the transmitter of FIG. 1 for pilot symbol encoding. The pilot symbols are predetermined control signals that may be used for channel estimation and other functions as will be described in detail. Operation of the STTD encoder 112 will be explained with reference to TABLE 1. The STTD encoder receives pilot symbol 11 at symbol time T, pilot symbol S_1 at symbol time $2T$, pilot symbol 11 at symbol time $3T$ and pilot symbol S_2 at symbol time $4T$ on lead 100 for each of sixteen time slots of a frame. For a first embodiment of the present invention having a data rate of

preferably 32 KSPS, the STTD encoder produces a sequence of four pilot symbols for each of two antennas corresponding to leads 204 and 206, respectively, for each of the sixteen time slots of TABLE 1. The STTD encoder produces pilot symbols B_1, S_1, B_2 and S_2 at symbol times T-$4T$, respectively, for a first antenna at lead 204. The STTD encoder simultaneously produces pilot symbols B_1, $-S_2^*$, $-B_2$ and S_1^* at symbol times T-$4T$, respectively, at lead 206 for a second antenna. Each symbol includes two bits representing a real and imaginary component. An asterisk indicates a complex conjugate operation or sign change of the imaginary part of the symbol. Pilot symbol values for the first time slot for the first antenna at lead 204, therefore, are 11, 11, 11 and 11. Corresponding pilot symbols for the second antenna at lead 206 are 11, 01, 00 and 10.

[0012] The bit signals of these symbols are transmitted serially along respective paths 208 and 210. Each bit signal of a respective symbol is subsequently received at a remote mobile antenna 212 after a transmit time τ_j corresponding to the j^{th} path. The signals propagate to a despreader input circuit (FIG. 4A) where they are summed over each respective symbol time by circuit 406 to produce output signals R_j^1, R_j^2, R_j^3 and R_j^4. These output signals correspond to the four pilot symbol time slots and the j^{th} of L multiple signal paths as previously described. These output signals are delayed by delay circuit 410 to produce simultaneous output signals.

[0013] These simultaneous output signals are applied as input signals to channel estimation circuit 422 (FIG. 4B). The channel estimation circuit 422 also receives known symbol signals $S_{1,i}$ and $S_{2,i}$, corresponding to the i^{th} time slot of the frame. Thus, the path specific input signals together with corresponding known pilot symbols for a specific time slot are applied to the channel estimation circuit to determine separate Rayleigh fading channel estimates at leads 428 and 430 for each respective time slot.

TABLE 1

	ANTENNA 1				ANTENNA 2			
SLOT	B_1	S_1	B_2	S_2	B_1	$-S_2^*$	$-B_2$	S_1^*
1	11	11	11	11	11	01	00	10
2	11	11	11	01	11	11	00	10
3	11	01	11	01	11	11	00	00
4	11	10	11	01	11	11	00	11
5	11	10	11	11	11	01	00	11
6	11	10	11	11	11	01	00	11
7	11	01	11	00	11	10	00	00
8	11	10	11	01	11	11	00	11
9	11	11	11	00	11	10	00	10
10	11	01	11	01	11	11	00	00
11	11	11	11	10	11	00	00	10
12	11	01	11	01	11	11	00	00
13	11	00	11	01	11	11	00	01
14	11	10	11	00	11	10	00	11
15	11	01	11	00	11	10	00	00
16	11	00	11	00	11	10	00	01

[0014] The input signals corresponding to the pilot symbols for each time slot are given in equations [5-8]. Noise terms are omitted for simplicity. Received signal R_j^1 is produced by pilot symbols (B_1, B_1) having a constant value (11,11) at symbol time T for all time slots. Thus, the received signal is equal to the sum of respective Rayleigh fading parameters corresponding to the first and second antennas. Likewise, received signal R_j^3 is produced by pilot symbols (B_2,$-B_2$) having a constant value (11,00) at symbol time $3T$ for all time slots. Received signals R_j^2 and R_j^4, corresponding to symbol times $2T$ and $4T$, have values (S_1,$-S_2^*$) and (S_2,S_1^*), respectively, as indicated by TABLE 1. Channel estimates for the Rayleigh fading parameters corresponding to the first and second antennas, therefore, are readily determined from the input signals as in equations [9] and [10].

$$R_j^1 = \alpha_j^1 + \alpha_j^2 \quad [5]$$

$$R_j^2 = \alpha_j^1 S_{1,i} - \alpha_j^2 S_{2,i}^* \quad [6]$$

$$R_j^3 = \alpha_j^1 - \alpha_j^2 \quad [7]$$

$$R_j^4 = \alpha_j^1 S_{2,i} + \alpha_j^2 S_{1,i}^* \quad [8]$$

$$\alpha_j^1 = (R_j^1 + R_j^2 S_{1,i}^* + R_j^3 + R_j^4 S_{2,i}^*)/4 \quad [9]$$

$$\alpha_j^2 = (R_j^1 - R_j^2 S_{2,i} - R_j^3 + R_j^4 S_{1,i})/4 \quad [10]$$

[0015] Referring now to FIG. 3, there is a schematic diagram of a phase correction circuit of the present invention that may be used with a remote mobile receiver. This phase correction circuit receives input signals, for example, R_j^m and R_j^n on leads 324 and 326 corresponding to symbol times within the same time slot as the pilot symbols used for channel estimates. The phase correction circuit receives a complex conjugate of a channel estimate of a Rayleigh fading parameter α_j^{1*} corresponding to the first antenna on lead 302 and a channel estimate of another Rayleigh fading parameter α_j^2 corresponding to the second antenna on lead 306. Complex conjugates of the input signals are produced by circuits 308 and 330 at leads 310 and 322, respectively. These input signals and their complex conjugates are multiplied by Rayleigh fading parameter estimate signals and summed as indicated to produce path-specific symbol estimates at respective output leads 318 and 322 as in equations [11] and [12].

$$R_j^m \alpha_j^{1*} + R_j^{n*} \alpha_j^2 = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_m \quad [11]$$

$$-R_j^{m*} \alpha_j^2 + R_j^n \alpha_j^{1*} = (|\alpha_j^1|^2 + |\alpha_j^2|^2) S_n \quad [12]$$

These path-specific symbol estimates are then applied to a rake combiner circuit to sum individual path-specific symbol estimates, thereby providing net soft symbols or pilot symbol signals as in equations [13] and [14].

$$\tilde{S}_m = \sum_{j=1}^{L} R_j^m \alpha_j^{1*} + R_j^{n*} \alpha_j^2 \quad [13]$$

$$\tilde{S}_n = \sum_{j=1}^{L} -R_j^{m*} \alpha_j^2 + R_j^n \alpha_j^{1*} \quad [14]$$

These soft symbols or estimates provide a path diversity *L* and a transmit diversity *2*. Thus, the total diversity of the STTD system is *2L*. This increased diversity is highly advantageous in providing a reduced bit error rate.

[0016] Although the invention has been described in detail with reference to its preferred embodiment, it is to be understood that this description is by way of example only and is not to be construed in a limiting sense. For example, the pilot symbol patterns of TABLE 1 are suitable for data rates of 16, 32, 64 and 128 KSPS having four pilot symbols in each time slot. Other patterns produce a similar result. The pattern of TABLE 2, for example, applied to the second antenna produces the same result.

TABLE 2

SLOT	B_2^*	$-S_2^*$	$-B_1^*$	S_1^*
1	10	01	01	10
2	10	11	01	10
3	10	11	01	00
4	10	11	01	11
5	10	01	01	11
6	10	01	01	11

TABLE 2 (continued)

SLOT	B_2^*	$-S_2^*$	$-B_1^*$	S_1^*
7	10	10	01	00
8	10	11	01	11
9	10	10	01	10
10	10	11	01	00
11	10	00	01	10
12	10	11	01	00
13	10	11	01	01
14	10	10	01	11
15	10	10	01	00
16	10	10	01	01

[0017] A change of pilot symbols from (B_1,B_1) to $(B_2^*,-B_1^*)$ in TABLE 2 produces equations [15-18] corresponding to previous equations [5-8], respectively. Thus, the channel estimates are readily determined as in equations [20] and [21], corresponding to previous equations [9] and [10], respectively.

$$R_j^1 = \alpha_j^1 B_1 + \alpha_j^2 B_2^* \quad [15]$$

$$R_j^2 = \alpha_j^1 S_{1,i} - \alpha_j^2 S_{2,i}^* \quad [16]$$

$$R_j^3 = \alpha_j^1 B_2 - \alpha_j^2 B_1^* \quad [17]$$

$$R_j^4 = \alpha_j^1 S_{2,i} + \alpha_j^2 S_{1,i}^* \quad [18]$$

$$\alpha_j^1 = (R_j^1 B_1^* + R_j^2 S_{1,i}^* + R_j^3 B_2^* + R_j^4 S_{2,i}^*)/4 \quad [20]$$

$$\alpha_j^2 = (R_j^1 B_2 - R_j^2 S_{2,i} - R_j^3 B_1 + R_j^4 S_{1,i})/4 \quad [21]$$

The inventive concept of the present invention is readily adaptable to other data rates having a number of pilot symbols other than four. For example, TABLE 3 and TABLE 4 give the pilot symbol patterns for data rates with two and eight pilot symbols in each time slot for the first and second antennas, respectively. Likewise, TABLE 5 and TABLE 6 give the pilot symbol patterns for data rates with sixteen pilot symbols in each time slot for the first and second antennas, respectively.

TABLE 3

	8 KSP		256, 512, 1024 KSPS							
SLOT	0	1	0	1	2	3	4	5	6	7
1	11	11	11	11	11	11	11	11	11	10
2	11	11	11	10	11	10	11	10	11	01
3	11	10	11	10	11	01	11	11	11	01
4	11	01	11	11	11	01	11	00	11	10
5	11	10	11	11	11	00	11	01	11	10
6	11	10	11	11	11	11	11	01	11	10
7	11	01	11	10	11	11	11	01	11	10
8	11	00	11	01	11	00	11	10	11	00
9	11	00	11	11	11	10	11	00	11	01

TABLE 3 (continued)

	8 KSP		256, 512, 1024 KSPS							
SLOT	0	1	0	1	2	3	4	5	6	7
10	11	10	11	01	11	11	11	11	11	00
11	11	10	11	10	11	10	11	11	11	10
12	11	11	11	01	11	10	11	10	11	00
13	11	10	11	10	11	01	11	11	11	10
14	11	11	11	00	11	10	11	10	11	00
15	11	00	11	01	11	10	11	00	11	00
16	11	00	11	10	11	00	11	00	11	00

TABLE 4

	8 KSPS		256, 512, 1024 KSPS							
SLOT	0	1	0	1	2	3	4	5	6	7
1	11	11	11	01	00	10	11	00	00	10
2	11	11	11	00	00	11	11	11	00	11
3	11	10	11	11	00	11	11	11	00	10
4	11	01	11	11	00	10	11	00	00	01
5	11	10	11	10	00	10	11	00	00	00
6	11	10	11	01	00	10	11	00	00	00
7	11	01	11	01	00	11	11	00	00	00
8	11	00	11	10	00	00	11	10	00	11
9	11	00	11	00	00	10	11	11	00	01
10	11	10	11	01	00	00	11	10	00	10
11	11	10	11	00	00	11	11	00	00	10
12	11	11	11	00	00	00	11	10	00	11
13	11	10	11	11	00	11	11	00	00	10
14	11	11	11	00	00	01	11	10	00	11
15	11	00	11	00	00	00	11	10	00	01
16	11	00	11	10	00	11	11	10	00	01

TABLE 5

	2048, 4096 KSPS															
SLOT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11	01	11	10	11	11	11	10	11	01	11	00	11	00	11	01
2	11	01	11	01	11	10	11	11	11	01	11	01	11	10	11	01

TABLE 5 (continued)

	2048, 4096 KSPS															
SLOT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3	11	01	11	10	11	00	11	01	11	11	11	11	11	01	11	10
4	11	11	11	11	11	01	11	01	11	11	11	01	11	00	11	01
5	11	00	11	00	11	11	11	01	11	10	11	00	11	11	11	11
6	11	00	11	11	11	10	11	01	11	10	11	00	11	10	11	11
7	11	01	11	00	11	10	11	00	11	10	11	10	11	01	11	01
8	11	01	11	00	11	11	11	10	11	11	11	10	11	11	11	00
9	11	11	11	11	11	01	11	11	11	11	11	10	11	10	11	01
10	11	10	11	01	11	10	11	10	11	10	11	00	11	11	11	00
11	11	00	11	01	11	11	11	01	11	01	11	01	11	01	11	11
12	11	11	11	00	11	10	11	10	11	00	11	01	11	00	11	11
13	11	11	11	11	11	11	11	00	11	00	11	10	11	11	11	11
14	11	00	11	01	11	10	11	10	11	00	11	00	11	00	11	10
15	11	00	11	11	11	10	11	00	11	10	11	01	11	01	11	11
16	11	00	11	00	11	00	11	11	11	00	11	10	11	01	11	00

TABLE 6

	2048, 4096 KSPS															
SLOT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	11	00	00	00	11	00	00	10	11	10	00	00	11	11	00	01
2	11	11	00	00	11	01	00	11	11	11	00	00	11	11	00	11
3	11	00	00	00	11	11	00	01	11	01	00	10	11	00	00	00
4	11	01	00	10	11	11	00	00	11	11	00	10	11	11	00	01
5	11	10	00	01	11	11	00	10	11	10	00	11	11	01	00	10
6	11	01	00	01	11	11	00	11	11	10	00	11	11	01	00	11
7	11	10	00	00	11	10	00	11	11	00	00	11	11	11	00	00
8	11	10	00	00	11	00	00	10	11	00	00	10	11	10	00	10
9	11	01	00	10	11	01	00	00	11	00	00	10	11	11	00	11
10	11	11	00	11	11	00	00	11	11	10	00	11	11	10	00	10
11	11	11	00	01	11	11	00	10	11	11	00	00	11	01	00	00
12	11	10	00	10	11	00	00	11	11	11	00	01	11	01	00	01
13	11	01	00	10	11	10	00	10	11	00	00	01	11	01	00	10
14	11	11	00	01	11	00	00	11	11	10	00	01	11	00	00	01
15	11	01	00	01	11	10	00	11	11	11	00	11	11	01	00	00
16	11	10	00	01	11	01	00	01	11	00	00	01	11	10	00	00

[0018] It is understood that the inventive concept of the present invention may be embodied in a mobile communi-

cation system as well as circuits within the mobile communication system. It is to be further understood that numerous changes in the details of the embodiments of the invention will be apparent to persons of ordinary skill in the art having reference to this description.
For example, alternative embodiments envisaged by the inventors include:

- the total path diversity of each of the first and second symbol signals is at least twice the number of transmitting antennas;
- the plurality of input signals includes four input signals, each of the four input signals including at least one pilot symbol signal, and the at least one known signal including two known pilot symbol signals;
- the first input signal of the plurality of input signals is transmitted from a first antenna and a second input signal of the plurality of input signals is transmitted by a second antenna;
- each of the plurality of input signals includes at least one pilot symbol;
- the plurality of input signals being wideband code division multiple access signals received in a transmitted frame, and the plurality of input signals being received during a time slot of the frame;
- an input circuit coupled to receive a plurality of signals from the external source along a plurality of signal paths, the input circuit producing the plurality of input signals such that each input signal corresponds to at least two signals;
- a combining circuit coupled to receive a plurality of first symbol estimates including the first symbol estimate and a plurality of second symbol estimates including the second symbol estimate, the correction circuit producing at least one first symbol signal in response to the plurality of first symbol estimates and at least one second symbol signal in response to the plurality of second symbol estimates;
- the input circuit, the estimate circuit, the correction circuit and the combining circuit are formed on a single integrated circuit;
- each of the first and second input signals is a wideband code division multiple access signal.

[0019] It is contemplated that these and other such changes and additional embodiments are within the spirit and true scope of the invention.

Claims

1. Circuitry comprising:

an estimate circuit coupled for receiving a plurality of input signals from an external source along a plurality of paths and at least one known signal, the at least one known signal having a predetermined value, the estimate circuit arranged for producing a plurality of estimate signals corresponding to each respective signal path in response to the plurality of input signals and the at least one known signal; and
a correction circuit coupled for receiving the plurality of estimate signals and the plurality of input signals, the correction circuit arranged for producing a first symbol estimate in response to the plurality of estimate signals and the plurality of input signals, the correction circuit further arranged for producing a second symbol estimate in response to the plurality of estimate signals and the plurality of input signals.

2. Circuitry as in claim 1, wherein each of the plurality of input signals includes at least one pilot symbol.

3. Circuitry as in claim 2, wherein the plurality of input signals are wideband code division multiple access signals received in a transmitted frame and wherein the plurality of input signals are received from a time slot of the frame.

4. Circuitry as in any preceding claim further comprising:

an input circuit coupled for receiving a plurality of bit signals from the external source along a plurality of signal paths, the input circuit arranged for producing the plurality of input signals, each input signal corresponding to at least two signals.

5. Circuitry as in any preceding claim further comprising:

a combining circuit coupled for receiving a plurality of first symbol estimates including the first symbol estimate and a plurality of second symbol estimates including the second symbol estimate, the correction circuit arranged for producing at least one first symbol signal in response to the plurality of first symbol estimates and at least one second symbol signal in response to the plurality of second symbol estimates.

6. Circuitry as in any preceding claim, wherein each of the plurality of estimate signals is a Rayleigh fading parameter estimate.

7. A method of processing signals in a communication circuit comprising:

receiving a plurality of groups of predetermined signals during a predetermined period from an external source along plural signal paths, each group of the plurality of groups being equally spaced apart from another group in time; and
producing at least two estimate signals corresponding to each path of the plural signal paths in response to each group and at least one known signal.

8. A method of processing signals in a communication circuit as in claim 7, wherein the step of producing at least two estimate signals includes producing at least two Rayleigh fading parameter estimate signals corresponding to each path of the plural signal paths.

9. A method of processing signals in a communication circuit as in claim 7 or claim 8, wherein said each group is a group of pilot symbols in a respective time slot and wherein said being equally spaced apart includes being spaced apart in another time slot.

10. A method of processing signals in a communication circuit as in any of claims 7 to 9, further comprising the steps of:

receiving a plurality of input signals from the external source; and
producing a plurality of symbol estimate signals in response to respective said at least two estimate signals and said plurality of input signals.

11. A method of processing signals as in any of claims 7 to 10, further comprising the steps of:

combining symbol estimate signals corresponding to different paths from said plurality of symbol estimate signals; and
producing a symbol signal in response to said step of combining.

12. A mobile communication system, comprising:

a mobile antenna arranged to receive a plurality of input signals from an external source along a respective plurality of signal paths;
an estimate circuit coupled to receive the plurality of input signals from the mobile antenna and at least one known signal, the at least one known signal having a predetermined value, the estimate circuit producing a plurality of estimate signals corresponding to each respective signal path in response to the plurality of input signals and the at least one known signal; and
a correction circuit coupled to receive the plurality of estimate signals and the plurality of input signals, the correction circuit producing a first symbol estimate in response to the plurality of estimate signals and the plurality of input signals, the correction circuit producing a second symbol estimate in response to the plurality of estimate signals and the plurality of input signals.

13. A mobile communication system as in claim 12, wherein each of the plurality of estimate signals is a Rayleigh fading parameter estimate.

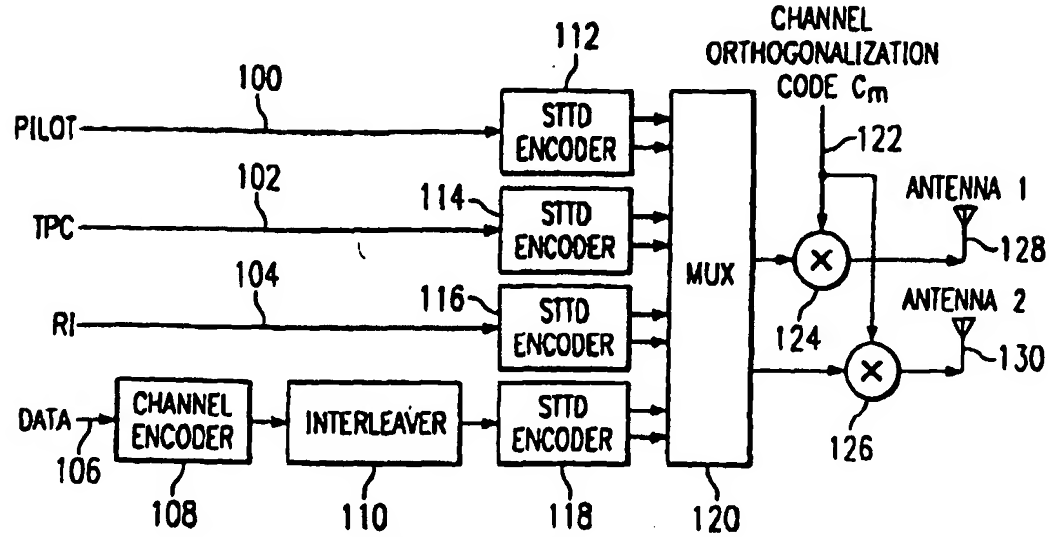


FIG. 1

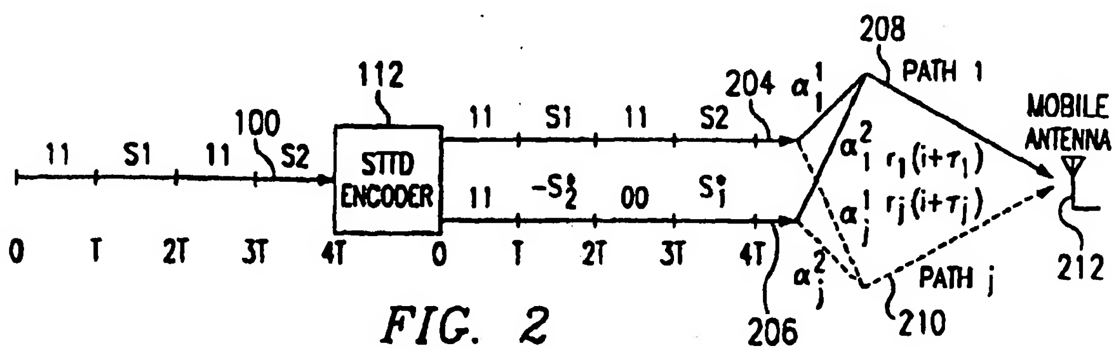


FIG. 2

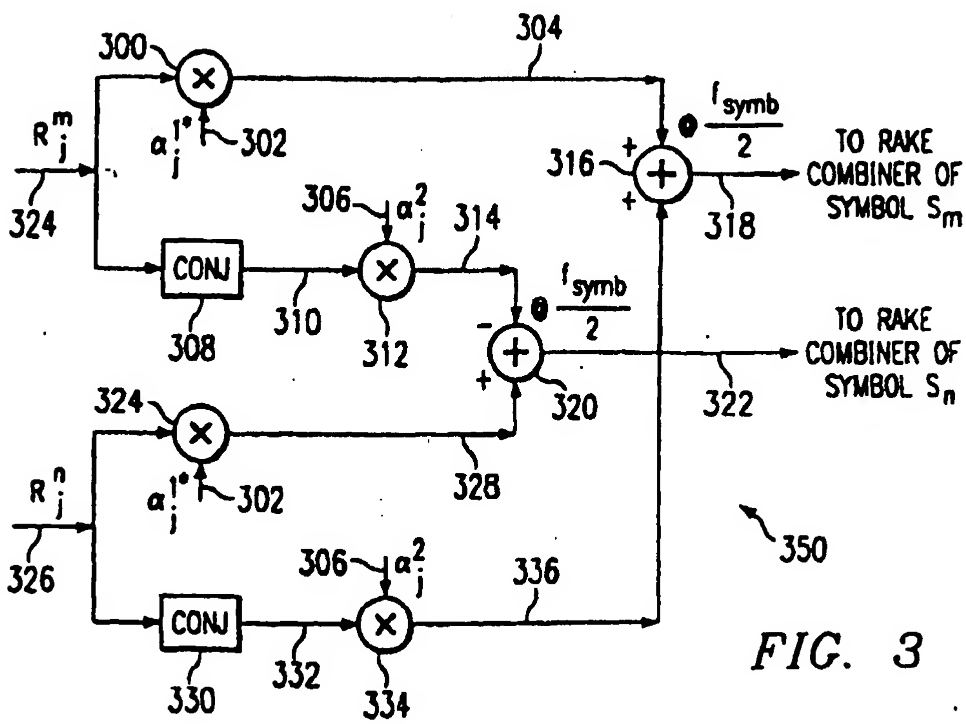


FIG. 3

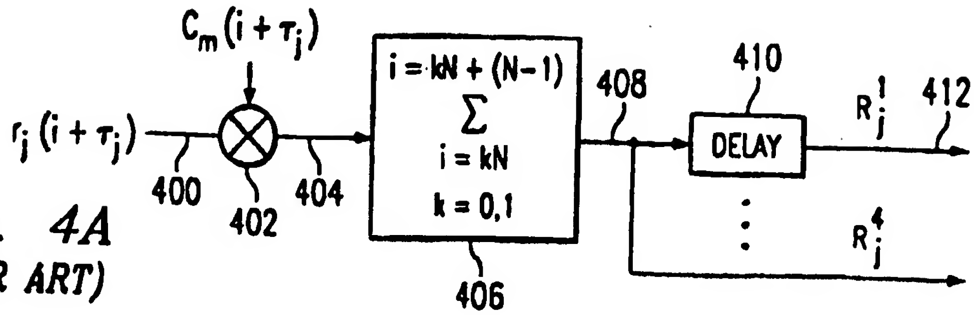


FIG. 4A
(PRIOR ART)

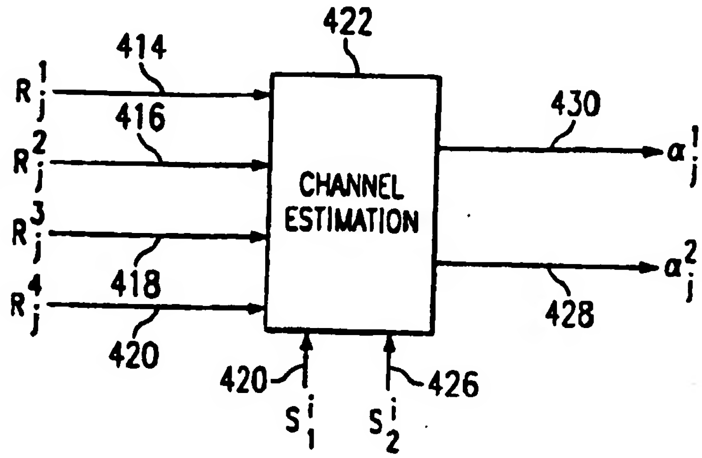


FIG. 4B

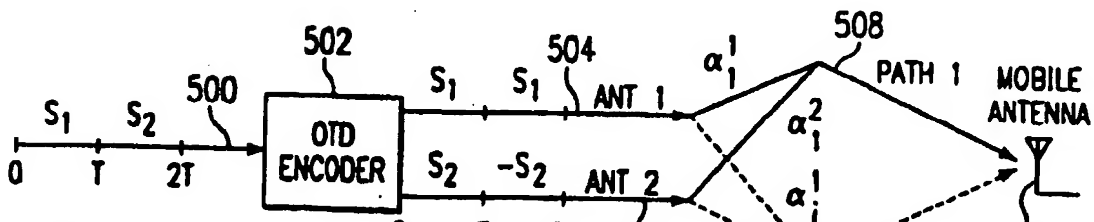


FIG. 5
(PRIOR ART)

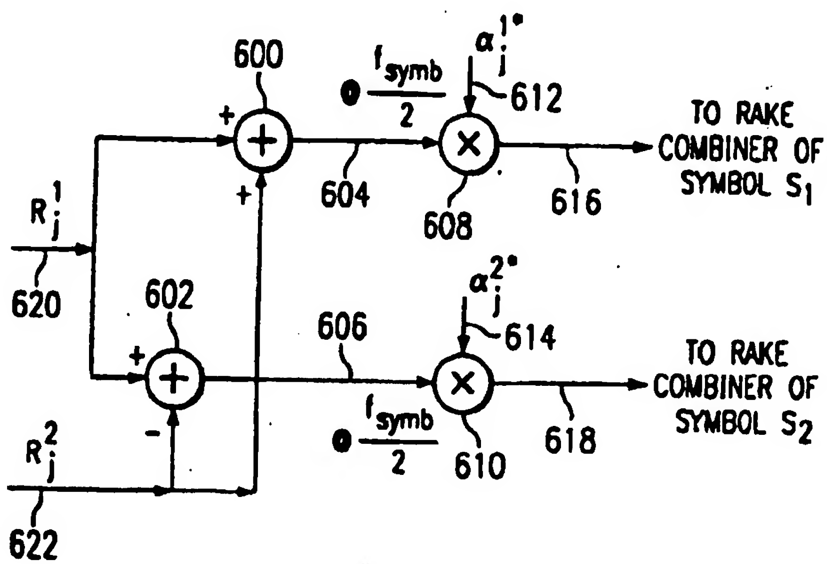


FIG. 6
(PRIOR ART)